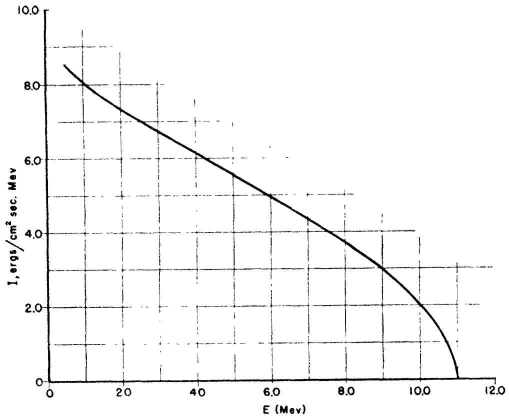

FIG. 3. Approximate intensity spectrum of the Naval Ordnance Laboratory betatron when run at "10 r/min. at 1 m," at 1.5 m from the target.

the high energies parallels results obtained at Illinois[7] at somewhat higher energies (20 Mev). If we assume the fit with Schiff's theory to be good enough, the comparison of the theoretical distribution with our experiment determines the approximate normalization factor. The intensity spectrum under the stated conditions in absolute units is given in Fig. 3.

We appreciate the kindness of Mr. D. T. O'Connor of the Naval Ordnance Laboratory for making the betatron available for our use. We wish also to extend our appreciation to Dr. U. Fano for several discussions and to Drs. N. P. Heydenburg and W. D. Whitehead for providing the D−D neutrons.

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The Excess of Negative over Positive Mesons Produced by High Energy Photons

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MESONS produced by the high energy photon beam from the University of California Radiation Laboratory 330 Mev synchrotron are found to show an excess of negatives over positives.[1] With a carbon target, observing mesons in the energy range 30–130 Mev at 90° to the photon beam, the ratio of negative to positive mesons is 1.7 ± 0.2 with no significant energy dependence.

A simple classical argument can be made to give an understanding of the reason for the negative excess. The photon can interact directly with the meson and proton through the current coupling

$$(\mathbf{j}\cdot\mathbf{A})(\text{meson})+(\mathbf{j}\cdot\mathbf{A})(\text{proton}).$$

The meson contribution is symmetrical for the production of positive and negative mesons. However, when positive mesons are produced, the proton is the initial nucleon at rest, and its current is zero. When negative mesons are produced, the proton is the final recoil nucleon giving a current contribution. Therefore, the cross sections for the production of positive and negative mesons are in the ratio

$$\frac{\sigma(\text{positives})}{\sigma(\text{negatives})}=\left[\frac{(\mathbf{j}\cdot\mathbf{A})(\text{meson})}{(\mathbf{j}\cdot\mathbf{A})(\text{meson})+(\mathbf{j}\cdot\mathbf{A})(\text{recoil proton})}\right]. \quad (1)$$

The current interaction is

$$\mathbf{j}\cdot\mathbf{A}=\frac{e\mathbf{v}\cdot\mathbf{A}}{1-(v/c)\cos\theta},$$

where

$\mathbf{v}$ = velocity of particle
$\mathbf{A}$ = vector potential
$\cos\theta$ = angle between direction of particle and photon.

This differs from the non-relativistic expression, $e\mathbf{v}\cdot\mathbf{A}$, the factor $1-v/c\cos$ in the denominator taking account of the retardation effects in the interaction of charge with the electromagnetic field. Inserting this current expression and using over-all energy and momentum conservation, the positive to negative ratio can be written

$$\frac{\sigma(\text{positives})}{\sigma(\text{negatives})}=\left[1-\frac{\epsilon}{\mathrm{m}c^2}\left(1-\frac{v}{c}\cos\theta\right)\right]^2, \quad (2)$$

where

ϵ = meson energy including rest energy
v = meson velocity
θ = angle between direction of meson and photon
m = nucleon rest mass.

Further calculations have been carried out using standard perturbation theory for scalar and pseudoscalar mesons to the lowest order in the coupling constants g and e, treating the nucleons as Dirac particles and taking into account the effects of the nucleon recoil. The result of these calculations, for the ratio of the cross sections for positive and negative mesons, is exactly the same as that derived by the above simple considerations. Similar calculations for vector mesons with vector coupling to the nucleon field are complicated by the strong magnetic moment interaction of the vector particle with the e.m. field. The ratio of negative to positive mesons is similar to that for the scalar meson fields but is somewhat larger.

The effects of the Coulomb field of the nucleus on the production of mesons have also been investigated and found to be less than 5 percent for mesons with energies above 30 Mev.

The ratio of the cross sections for the production of negative and positive mesons given by (1) varies from 1.55 at 40 Mev to 1.83 at 100 Mev, at 90° to the photon beam. This agrees, within the probable error with the experimentally observed ratio. Since the positive-negative ratio depends in a quite direct way on the currents carried by the mesons and nucleons, a more accurate determination of the ratio and its energy dependence could provide valuable evidence concerning the magnetic moments of the particles.

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The Beta-Spectra of Cu^{64}

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IN a previous paper,[1] results were reported which indicated that the negatron and positron spectra of Cu^{64} have more particles at low energy than is predicted by the Fermi theory of beta-decay. It was later reported by Wu and Albert[2] that this deviation appeared to be a function of the source thickness over the same range of values for which no such effect had been observed in the earlier work. Subsequently, we made a study of autoradiographs of sources prepared from chemical solutions. It was found that in general such sources, though appearing to be uniform, may in many cases have variations in intensity of as much as 100 to 1. Under these circumstances, the *average* thickness of a source as reported by different investigators does not have much meaning.

In order to remove this difficulty, we have attempted to remeasure the Cu^{64} spectra using sources prepared by thermal evaporation of metallic Cu in vacuum. Two sources were used.